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(54) THREE-DIMENSIONAL COMPLEX COIL

DREIDIMENSIONALE KOMPLEXSPULE

BOBINE COMPLEXE TRIDIMENSIONNELLE

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Description

BACKGROUND OF THE INVENTION

[0001] The prior art contemplates a number of methods and devices for treating a body aneurysm using three-dimensional (3-D) shaped coils, sometimes referred to as "complex" coils. For example, Horton 5,766,219, the contents of which are incorporated by reference, shows a hollow structure. Phelps 5,382,259 and Ritchart 4,994,069 show other 3-D coil designs. Teoh 6,635,069 teaches a series of nonoverlapping loops. Wallace 6,860,893 shows complex coils. Ferrera 6,638,291 shows a device similar to Teoh's and Wallace's except that a J-shaped proximal segment extends away from the complex portion of the device.

[0002] The following patents provide further background Guglielmi 6,010,498; Gandhi 6,478,773; Schaefer 2002/0107534; Mariant 5,957,948; Pham 5,911,731; Lahille 4,957,501; Porter 2005/0192618; Wallace 2005/0192621.

[0003] There is, however an ongoing need to provide more advanced and improved complex coils so as to provide better treatment of an aneurysm.

[0004] WO0074577 discloses a medical device for forming an embolism within the vasculature of a patient.

[0005] US5639277 discloses a surgical device that is for forming a vasoocclusion or embolism. Typically, it is a helically wound coil in which the helix is wound in such a way as to have multiple axially offset, longitudinal or focal axes.

[0006] US20020107534 discloses a vaso-occlusive device that includes a microcoil formed into a minimum energy state secondary configuration comprising a plurality of curved segments, each defining a discrete axis, whereby the device, in its minimum energy state configuration, defines multiple axes.

[0007] WO9409705 relates to a vasoocclusion coil which may be segmented.

[0008] US6322576 discloses device discloses a vaso-occlusive device with a complex, three-dimensional structure in a relaxed configuration that may be used in the approximate shape of an anatomical cavity.

OBJECTS AND SUMMARY OF THE INVENTION

[0009] It is therefore an object of the invention to provide improved devices and methods for treating an aneurysm over the prior art.

[0010] The invention is defined by the claims.

[0011] This object and other objects not specifically enumerated here are addressed by embodiments of the invention, at least one embodiment of which includes a toroid-shaped device wound around a fixture such that portions of the device's length meet or overlap in the center of the toroid. This allows the outer portion of the device to form a scaffold while the interior portion of the device provides occlusion to prevent the influx of blood and promote thrombus formation.

[0012] One embodiment includes a strand of material that self-forms into a toroid-shaped series of loops and is designed to provide a stable structure within the body cavity, allowing for occlusion of the cavity and serving as a framework to hold additional treatment devices.

[0013] Another embodiment of the present invention provides a strand of material that self-forms into a cruciform series of loops and is designed to provide a stable structure within the body cavity, allowing for occlusion of the cavity and serving as a framework to hold additional treatment devices.

[0014] In another aspect, the embodiment of invention includes tools and methods of manufacture to make the aforementioned embodiments of the invention.

[0015] In yet another aspect of the embodiments of present invention, an embodiment includes a cruciform device wound around a fixture comprising at least two parallel pins disposed at an angle to at least one additional pin. This construction allows the outer portion of the device to form a scaffold while the interior portion of the device provides occlusion to prevent the influx of blood and promote thrombus formation. This embodiment also advantageously resists rotating or tumbling during deployment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Figure 1 is a perspective view of an embodiment of a fixture and a complex coil ;

Figure 2 is a perspective view of an embodiment of a complex coil;

Figure 3 is a perspective view of an embodiment of a fixture and a complex coil ;

Figure 4 is a perspective view of a complex coil of the present invention;

Figures 5-8 are photographs of a complex coils around various fixtures;

Figures 9-10 are photographs of complex coils formed according to one of the methods;

Figure 11 is a perspective view of an embodiment of a complex coil formed around an embodiment of a fixture shown in phantom lines;

Figure 12 is a perspective view of an embodiment of a complex coil;

Figure 13 is a perspective view of an embodiment of a complex coil;

Figure 14 is a perspective view of an embodiment of a fixture;

Figure 15 is a front elevation of the fixture shown in Figure 14; and,

Figures 16-19 are photographs of several complex coils formed using methods and fixtures according to the embodiments.

DETAILED DESCRIPTION OF THE INVENTION

Toroid Three-Dimensional Coil

[0017] Referring now to the figures and first to Figures 1-6, a coil or complex coil 10 is described that is shaped using a toroid-shaped fixture 12. The coil 10 has been wrapped around the fixture 12 four times in Figure 1 such that four loops 14 are formed, each loop being positioned approximately 90 degrees from the adjacent loops. Wrapping the coil 10 around the fixture 12 causes the coil 10 to form into a complex shape when deployed into a body cavity such as a blood vessel or aneurysm. The device may be made from a length of wire that has been helically wound to form an elongate coil wire. Alternatively, the wire may be braided or knitted by methods known in the art to form a secondary shape. The wire is preferably a memory metal, such as Nitinol, but may be platinum, tantalum, tungsten, stainless steel, or other biocompatible material. Other materials, such as Dacron or Nylon fibers, biodegradable polymers such as polylactic or polyglycolic acid, and expansible or non-expansible hydrogel materials may be placed inside or outside the coil or braid structure to enhance the performance of the device.

[0018] For purposes of description only, an observation may be made regarding the shape of the complex coil 10 that results from wrapping the coiled wire around the toroid-shaped fixture 12. As illustrated in Figure 2, each of the loops 14a-d is roughly contained within respective planes 16a-d. The planes intersect with each other at approximately a common intersection axis 18 near the center of the complex coil 10. As one skilled in the art will realize, any loops formed around the toroid fixture 12 will only approximately be contained within such planes and the degree to which they are contained within these planes is only a function of how they are wound around the toroid and has little or no effect on their performance.

[0019] As shown in Figures 3 and 4, any number of loops may be used in forming a complex coil of the present invention. In Figure 3, a complex coil 20 is formed by wrapping eight loops 22 around the toroid-shaped fixture 12. The loops 22 are relatively evenly spaced around the toroid 12 but may be spaced in any number of configurations. The result is the eight-looped complex coil 20 shown in Figure 4.

[0020] Figures 5 and 6 show complex coils 30 being formed around a toroid fixture 12 using 16 loops 32. The loops 32 are grouped in sets of two such that only eight distinct loops appear.

[0021] One example used to treat conditions, such as cerebral aneurysms, includes a platinum/tungsten alloy complex coil (92% Pt, 8% W available from Sigmund Cohn Mount Vernon, NY) with a diameter in the range of about .125 mm to about .625 mm and a length of about 5 mm to about 1000 mm. The complex coil is formed around a ceramic or metallic toroid-shaped fixture similar to the fixtures 12 shown in Figs. 1, 3, 5, and 6. The winding pattern shown in Figs. 1-6 forms a first loop 14a around the toroid 12, then a second loop 14b approximately 180° around the toroid from the first loop. In this example, a figure 8 pattern is used to wind the first and second loops. A third loop 14c is then formed at an angle around the center of the toroid, typically 5° to 175°, to the second loop. A fourth loop 14d is formed using a figure 8 pattern from the third loop 14c. More loops 14 may be added depending on the desired device size.

[0022] Those skilled in the art will appreciate that one advantage to the toroid complex coil configuration is that it may be scaled to the size of the treatment site by changing the number of loops. For example, very small (0.5-3 mm) lesions may be treated with 2 to 4 loop configurations, medium sized (4-10 mm) with 4-12 loop configurations, large (over 10 mm) with 8-36 loop configurations, and so on. The loops can form a closed structure such as an "O" shape (e.g. circle, oval, square, ellipse, star, etc.) or can be open such as a "C" or "U" shape. The loops may be of any dimension and are typically scaled to the approximate size of the treatment site. In the previous example, the loops may range from 0.5 mm diameter to 50 mm diameter. In this regard, "diameter" should not be narrowly construed to imply a circular dimension. Rather, "diameter" is used broadly to encompass the approximate size and shape of a loop.

[0023] After winding, the fixture and complex coil are heat-set by methods known in the art. For example, a typical annealing step for platinum complex coils is approximately 1100° F (593°C) for 5-40 minutes.

[0024] Once annealed, the complex coil will approximately retain the wound shape when substantially unconstrained or in its minimum energy state. The complex coil may then be subject to further processing such as forming a tip, adding a coupling mechanism for attachment to a delivery system, placing hydrogel or fibers onto or within the complex coil, placing a stretch resistant member inside or outside the complex coil, etc. The complex coil can then be attached to a delivery system, which is well known in the art, such as those disclosed in U.S. Patent Application Serial Number 11/212,830, entitled *Thermal Detachment System for Implantable* Devices. Other examples of delivery systems are disclosed in Guglielmi 6,010,498 or Gandhi 6,478,773. Once attached to the delivery pusher, the complex coil is placed in a substantially linear configuration within a tube for delivery to the treatment site.

[0025] In a typical procedure, the linear complex coil is fed through a conduit such as a microcatheter by advancing it through the conduit with the delivery pusher. Upon exiting the microcatheter, the complex coil then self-forms into a structure within the treatment site that approximates its annealed shape.

[0026] The fixture 12 used to create the implant is shown as a closed circular toroid. However, other non-circular shapes such as elliptical, square, and star-shaped patterns may be used. In addition, the toroid does not need to be a closed structure. In fact, it may be easier to wind if a gap is left within the structure so that tension can be kept on the complex coil by hanging a weight.

Cruciform Three-Dimensional Coil

[0027] Referring now to Figures 7-12, the production of complex coils 40 are shown using a fixture 42 that includes a plurality of pins 44 arranged at right angles to each other. Like the embodiments shown in Figures 1-6, the embodiments of the complex coils 40 formed using the fixture 42 in Figures 7-12 may be made from a length of wire that has been helically wound to form a coiled wire. Alternatively, the wire may be braided or knitted by methods known in the art to form a secondary shape. The wire may be platinum, tantalum, tungsten, stainless steel, Nitinol, or other biocompatible material. Other materials, such as Dacron or Nylon fibers, biodegradable polymers such as polylactic or polyglycolic acid, and expansible or non-expansible hydrogel materials may be placed inside or outside the complex coil or braid structure to enhance the performance of the device. By way of example only, one embodiment might be used to treat such conditions as cerebral aneurysms, employs a platinum/tungsten alloy complex coil 10 (92% PT, 8% W available from Sigmund Cohn Mount Vernon, NY) with a diameter in the range of about 0.125 mm to about 0.625 mm and a length of about 5 mm to about 1000 mm.

[0028] The complex coil 40 is formed by wrapping a coiled wire around the fixture 42, as shown in Figures 7-8. The fixture 42 is preferably a ceramic or metallic cruciform fixture and includes a plurality of pins 44 arranged at right angles to each other along axes x, y, and z. More specifically, the fixture 42 includes two pins 44x that are parallel to the x-axis, two pins 44y that are parallel to the y-axis, and two pins 44z that are parallel to the z-axis.

[0029] An example of a complex coil 40 that can be made using the fixture 42 of Figures 7-8 is shown in Figures 9-12. The winding pattern in this embodiment, shown most clearly in Figures 11-12, forms a first loop 46a around a first pin $44y_1$, then a second loop 46b around a second pin $44x_1$ that is disposed at an angle to the first pin $44y_1$. In this embodiment the angle between the loops 46a and 46b is approximately 45°-135°. A third loop 46c is then formed in approximately the same plane as the second loop 46b. In this example, the third loop 46c is formed around pin $44x_2$ in a figure 8 pattern with the second loop 46b. A fourth loop 46d is then formed at an angle with the third loop 46c. In this example, the fourth loop 46d is approximately 45°-135° to the third loop and is formed around pin $44y_2$ and is also approximately coplanar to the first loop 46a. A fifth loop 46e is then formed at an angle to the fourth loop 46d by wrapping the wire around pin $44x_1$ spaced apart from loop 46b, also formed around pin $44x_1$. A sixth loop 46f lies in approximately the same plane as the fifth loop 46e in a figure 8 pattern with the fifth loop 46e. The sixth loop 46f is formed by wrapping the wire around pin $44x_2$ spaced apart from loop 46c, which is also formed around pin $44x_2$. In this example, the fifth loop 46e and the sixth loop 46f are approximately concentric with the second loop 46b and the third loop 46c, respectively.

[0030] Fewer than six loops may be used to form shorter complex coils, while additional loops may be wound to make a longer device. For example, the pins 44z shown in Figures 7-8 extend through the pins 44x and 44y and are thus being used to hold the pins 44x and 44y in place. However, if a longer device is desired, loops could be formed by wrapping wire around the portions of the pins 44z extending from the pins 44y.

[0031] Furthermore, those skilled in the art will appreciate that the same final result could be obtained by reversing the just-described winding pattern: i.e. winding a first loop around a first pin, winding a second loop in approximately the same plane as the first loop, winding a third loop at an angle to the second loop, winding a fourth loop at an angle to the third loop, winding a fifth loop in approximately the same plane as the fourth loop, winding a sixth loop at an angle to the fifth loop, and so on.

[0032] The loops can form a closed structure such as an "O" shape (e.g. circle, oval, square, ellipse, star, etc.) or can be open such as a "C" or "U" shape. The loops may be of any dimension and are typically scaled to the approximate size of the treatment site. In the previous example, the loops may range from 0.5 mm diameter to 50 mm diameter.

In this regard, "diameter" should not be narrowly construed to imply a circular dimension. Rather, diameter is used broadly to encompass the approximate size and shape of a loop.

[0033] For example, the coil 50 shown in Figure 13 has loops 52 that are open and closed. The open loops are formed by wrapping a wire around a pin but transitioning to an adjacent pin prior to completing an overlapping loop. More specifically, the complex coil 50 of Figure 13 has six loops 52a-f formed using the fixture 42 of Figures 7 and 8. Loop 52a is a complete loop formed around one of the pins 44y. The wire is then wrapped in a figure 8 pattern around two adjacent pins 44x to form open loops 52b and 52c. The wire is next wrapped completely around the other y pin, 44y to form complete loop 52d. Next, the wire is wrapped in a figure 8 pattern around the two pins 44y on the opposite side of pins 44x to form loops 52e and 52f. The loop 52e is open but the loop 52f is closed, being the last loop.

[0034] Further complexity may be introduced using the fixture 60 shown in Figures 14-15. The fixture 60 in Figures 14-15 also has a plurality of pins 62 but differs from the fixture 42 in Figures 7 and 8 in three substantive ways. First, the pins 62 extend in directions parallel with x- and y-axes, but there are no pins that extend parallel to a z-axis. Rather, rectangular blocks 64 extend along the z-axis. Second, there are only two concentric pins, $62x_1$ and $62x_2$ that extend parallel to the x-axis. Third, there are four pins $62y_{1-4}$, each having independent longitudinal axes. Winding using the fixture 60 results in complex coils 70 such as those shown in Figures 16-19. These figures show a complex coil 70 with first and second loops, 74a and 74b, that are substantially coplanar and arranged in a figure 8 pattern, as well as third and forth loops, 74c and 74d that are similarly substantially coplanar and arranged in a figure 8 pattern that is rotated from the figure 8 pattern of the first and second loops, 74a and 74b. The examples shown in Figures 16-19 show the two figure 8 patterns rotated 90 degrees relative to each other. Additionally, the complex coils 70 include fifth and sixth loops, 74e and 74f, which are relatively concentric.

[0035] After winding, the fixture and complex coil are heat-set by methods known in the art. For example, a typical annealing step for platinum complex coils is approximately 1100° F (593°C) for 5-60 minutes.

[0036] Once annealed, the complex coil will approximately retain the wound shape when substantially in a minimal energy state. The complex coil may then be subject to further processing such as forming a tip, adding a coupling mechanism for attachment to a delivery system, placing hydrogel or fibers onto or within the complex coil, placing a stretch resistant member inside or outside the complex coil, etc. The complex coil can then be attached to a delivery system, which is well known in the art, such as those disclosed in U.S. Patent Application Serial Number 11/212,830, entitled *Thermal Detachment System for Implantable* Devices. Other examples of delivery systems are disclosed in Guglielmi 6,010,498 or Gandhi 6,478,773. Once attached to the delivery pusher, the complex coil 10 is placed in a substantially linear configuration within a tube for delivery to the treatment site.

[0037] In the typical procedure, the linear complex coil is fed through a conduit such as a microcatheter by advancing it through the conduit with the delivery pusher. Upon exiting the microcatheter, the complex coil then self-forms into a structure within the treatment site that approximates its annealed shape.

[0038] Although the invention has been described in terms of particular embodiments and applications, one of ordinary skill in the art, in light of this teaching, can generate additional embodiments and modifications without departing from or exceeding the scope of the claimed invention as defined by the claims. Accordingly, it is to be understood that the drawings and descriptions herein are proffered by way of example to facilitate comprehension of the invention and should not be construed to limit the scope thereof, which is defined by the claims.

Claims

1. A complex coil (40, 50, 70) comprising:

   a first and second loop (46b, 46c; 52b, 52c; 74a, 74b) aligned to form a first figure 8 pattern in a first plane;
   a third and fourth loop (46e, 46f; 52e, 52f; 74c, 74d) aligned to form a second figure 8 pattern in a second plane; **characterized in that**
   said first and second plane are spaced apart and substantially parallel to each other, and said first figure 8 pattern and said second figure 8 pattern are facing each other.

2. The complex coil according to claim 1 wherein none of said first, second, third and fourth loops (46b, 46c; 52b, 52c; 74a, 74b; 46e, 46f; 52e, 52f; 74c, 74d) share a common longitudinal axis.

3. The complex coil according to claim 1 or 2 wherein said first figure 8 pattern is rotated within said first plane relative to said second figure 8 pattern.

4. The complex coil according to claim 3 wherein said first figure 8 pattern is rotated approximately 90 degrees within said first plane relative to said second figure 8 pattern.

5. The complex coil according to claim 1 wherein said first and third loops (46b, 46e; 52b, 52c) have a common longitudinal axis.

6. The complex coil according to claim 1 wherein said second and fourth loops (46c, 46f; 52e, 52f) have a common longitudinal axis.

7. The complex coil according to any of claims 1 to 6, further comprising fifth and sixth loops (46a, 46d; 52a, 52d; 74e, 74f) having longitudinal axes that are angled approximately 90 degrees relative to longitudinal axes of the first, second, third, and fourth loops (46b, 46c; 52b, 52c; 74a, 74b; 46e, 46f; 52e, 52f; 74c, 74d).

8. The complex coil according to claim 7 wherein said fifth and sixth loops have a common longitudinal axis(74e, 74f) .

9. A method of making a complex coil (40, 50, 70) comprising:

   forming a first and second loop (46b, 46c; 52b, 52c; 74a, 74b) in a first figure 8 pattern relatively contained in a first plane;
   forming a third and fourth loop (46e, 46f; 52e, 52f; 74c, 74d) in a second figure 8 pattern relatively contained in a second plane; **character-**

ized by
forming said first and second plane spaced apart and substantially parallel to each other; and
forming said first figure 8 pattern and said second figure 8 pattern to face each other.

10. The method according to claim 9 further comprising forming at least one loop (46d; 52d; 74f) connecting said first and second figure 8 patterns, said at least one complete loop (46d; 52d; 74f) defining a third plane that is perpendicular to said first and second planes.

11. The method according to claim 10 wherein forming at least one loop (46d; 52d; 74f) connecting said first and second figure 8 patterns comprises forming two loops (46a, 46d; 52a, 52d; 74e, 74f) defining a third and fourth planes that are both perpendicular to said first and second planes.

12. The method according to claim 11 wherein forming two loops (46a, 46d; 52a, 52d; 74e, 74f) defining a third and fourth planes that are both perpendicular to said first and second planes comprises two loops (46a, 46d; 52a, 52d; 74e, 74f) defining a third and fourth planes that are both perpendicular to said first and second planes and are further parallel to each other.

13. The method according to claim 9 wherein forming a first and second loop (52b, 52c) in a first figure 8 pattern relatively contained in a first plane comprises forming at least one open loop (52b, 52c), and/or wherein forming a third and a fourth loop (52e, 52f)in a second figure 8 pattern relatively contained in a second plane comprises forming at least one open loop (52e).

14. The method according to any of claims 9 to 13, wherein said complex coil (40, 50, 70) is a complex coil (40, 50, 70) according to any of claims 1 to 8, said method comprising using a fixture (42, 60) to form said complex coil (40, 50, 70).

Patentansprüche

1. Komplexe Spule (40, 50, 70), umfassend:

erste und zweite Schlaufe (46b, 46c; 52b, 52c; 74a, 74b), die so ausgerichtet sind, dass sie ein erstes 8-förmiges Muster in einer ersten Ebene bilden;
dritte und vierte Schlaufe (46e, 46f; 52e, 52f; 74c, 74d), die so ausgerichtet sind, dass sie ein zweites 8-förmiges Muster in einer zweiten Ebene bilden; **dadurch gekennzeichnet, dass**
die erste und zweite Ebene im Abstand zueinander und im Wesentlichen parallel zueinander angeordnet sind, und dass das erste 8-förmige Muster und das zweite 8-förmige Muster einander gegenüberliegen.

2. Komplexe Spule gemäß Anspruch 1, wobei keine der ersten, zweiten, dritten und vierten Schlaufe (46b, 46c; 52b, 52c; 74a, 74b; 46e, 46f; 52e, 52f; 74c, 74d) eine gemeinsame Längsachse miteinander teilen.

3. Komplexe Spule gemäß Anspruch 1 oder 2, wobei das erste 8-förmige Muster innerhalb der ersten Ebene in Bezug auf das zweite 8-förmige Muster gedreht ist.

4. Komplexe Spule gemäß Anspruch 3, wobei das erste 8-förmige Muster innerhalb der ersten Ebene in Bezug auf das zweite 8-förmige Muster um ungefähr 90 Grad gedreht ist.

5. Komplexe Spule gemäß Anspruch 1, wobei erste und dritte Schlaufe (46b, 46e; 52b, 52c) eine gemeinsame Längsachse haben.

6. Komplexe Spule gemäß Anspruch 1, wobei zweite und vierte Schlaufe (46c, 46f; 52e, 52f) eine gemeinsame Längsachse haben.

7. Komplexe Spule gemäß einem beliebigen der Ansprüche 1 bis 6, ferner fünfte und sechste Schlaufen (46a, 46d; 52a, 52d; 74e, 74f) umfassend, die Längsachsen haben, welche in Bezug auf die Längsachsen der ersten, zweiten, dritten und vierten Schlaufen (46b, 46c; 52b, 52c; 74a, 74b; 46e, 46f; 52e, 52f; 74c, 74d) in einem Winkel von ungefähr 90 Grad liegen.

8. Komplexe Spule gemäß Anspruch 7, wobei die fünfte und sechste Schlaufe eine gemeinsame Längsachse (74e, 74f) haben.

9. Verfahren zur Herstellung einer komplexen Spule (40, 50, 70), umfassend:

Bildung einer ersten und zweiten Schlaufe (46b, 46c; 52b, 52c; 74a, 74b) in einem ersten 8-förmigen Muster, das relativ in einer ersten Ebene enthalten ist;
Bildung einer dritten und vierten Schlaufe (46e, 46f; 52e, 52f; 74c, 74d) in einem zweiten 8-förmigen Muster, das relativ in einer zweiten Ebene enthalten ist;
Bildung einer ersten und zweiten Ebene, die im Abstand zueinander und im Wesentlichen parallel zueinander angeordnet sind,
Bildung des ersten 8-förmigen Musters und des zweiten 8-förmigen Musters, so dass sie einan-

der gegenüberliegen.

10. Verfahren gemäß Anspruch 9, ferner die Bildung mindestens einer Schlaufe (46d; 52d; 74f) umfassend, die das erste und zweite 8-förmige Muster verbindet, wobei die mindestens eine vollständige Schlaufe (46d; 52d; 74f) eine dritte Ebene definiert, die senkrecht zu der ersten und zweiten Ebene verläuft.

11. Verfahren gemäß Anspruch 10, wobei die Bildung mindestens einer Schlaufe (46d; 52d; 74f), die das erste und zweite 8-förmige Muster verbindet, die Bildung von zwei Schlaufen (46a, 46d; 52a, 52d; 74e, 74f) umfasst, die eine dritte und vierte Ebene definieren, welche beide senkrecht zu der ersten und zweiten Ebene verlaufen.

12. Verfahren gemäß Anspruch 11, wobei die Bildung von zwei Schlaufen (46a, 46d; 52a, 52d; 74e, 74f), die eine dritte und vierte Ebene definieren, die beide senkrecht zu der ersten und zweiten Ebene verlaufen, zwei Schlaufen (46a, 46d; 52a, 52d; 74e, 74f) umfasst, die eine dritte und vierte Ebene definieren, die beide senkrecht zu der ersten und zweiten Ebene verlaufen und ferner parallel zueinander verlaufen.

13. Verfahren gemäß Anspruch 9, wobei die Bildung einer ersten und zweiten Schlaufe (52b, 52c) in einem ersten 8-förmigen Muster, das relativ in einer ersten Ebene enthalten ist, die Bildung mindestens einer offenen Schlaufe (52b, 52c) umfasst, und/oder wobei die Bildung einer dritten und vierten Schlaufe (52e, 52f) in einem zweiten 8-förmigen Muster, das relativ in einer zweiten Ebene enthalten ist, die Bildung mindestens einer offenen Schlaufe (52e) umfasst.

14. Verfahren gemäß einem beliebigen der Ansprüche 9 bis 13, wobei es sich bei der komplexen Spule (40, 50, 70) um eine komplexe Spule (40, 50, 70) gemäß einem beliebigen der Ansprüche 1 bis 8 handelt, wobei das Verfahren die Verwendung einer Befestigung (42, 60) zur Bildung der komplexen Spule (40, 50, 70) umfasst.

Revendications

1. Bobine complexe (40, 50, 70) comprenant :

des première et deuxième boucles (46b, 46c ; 52b, 52c ; 74a, 74b) alignées pour former un premier motif de chiffre 8 dans un premier plan ; des troisième et quatrième boucles (46e, 46f ; 52e, 52f ; 74c, 74d) alignées pour former un deuxième motif de chiffre 8 dans un deuxième plan ; **caractérisée en ce que** lesdits premier et deuxième plans sont écartés et sont substantiellement parallèles l'un par rapport à l'autre, et ledit premier motif de chiffre 8 et ledit deuxième motif de chiffre 8 sont en face l'un de l'autre.

2. Bobine complexe selon la revendication 1 dans laquelle aucune desdites première, deuxième, troisième et quatrième boucles (46b, 46c ; 52b, 52c ; 74a, 74b ; 46e, 46f ; 52e, 52f ; 74c, 74d) ne partage un axe longitudinal commun.

3. Bobine complexe selon la revendication 1 ou 2 dans laquelle ledit premier motif de chiffre 8 est amené à tourner dans ledit premier plan par rapport audit deuxième motif de chiffre 8.

4. Bobine complexe selon la revendication 3 dans laquelle ledit premier motif de chiffre 8 est amené à tourner d'approximativement 90 degrés dans ledit premier plan par rapport audit deuxième motif de chiffre 8.

5. Bobine complexe selon la revendication 1 dans laquelle lesdites première et troisième boucles (46b, 46e ; 52b, 52c) ont un axe longitudinal commun.

6. Bobine complexe selon la revendication 1 dans laquelle lesdites deuxième et quatrième boucles (46c, 46f ; 52e, 52f) ont un axe longitudinal commun.

7. Bobine complexe selon l'une quelconque des revendications 1 à 6, comprenant en outre des cinquième et sixième boucles (46a, 46d ; 52a, 52d ; 74e, 74f) ayant des axes longitudinaux qui sont inclinés d'approximativement 90 degrés par rapport aux axes longitudinaux des première, deuxième, troisième, et quatrième boucles (46b, 46c ; 52b, 52c ; 74a, 74b ; 46e, 46f ; 52e, 52f ; 74c, 74d).

8. Bobine complexe selon la revendication 7 dans laquelle lesdites cinquième et sixième boucles ont un axe longitudinal commun (74e, 74f).

9. Procédé de fabrication d'une bobine complexe (40, 50, 70) comprenant les étapes consistant à :

former des première et deuxième boucles (46b, 46c ; 52b, 52c ; 74a, 74b) dans un premier motif de chiffre 8 contenu relativement dans un premier plan ;
former des troisième et quatrième boucles (46e, 46f ; 52e, 52f ; 74c, 74d) dans un deuxième motif de chiffre 8 contenu relativement dans un deuxième plan ; **caractérisé par** les étapes consistant à
former lesdits premier et deuxième plans écartés et substantiellement parallèles l'un par rap-

port à l'autre ; et
former ledit premier motif de chiffre 8 et ledit deuxième motif de chiffre 8 pour être en face l'un de l'autre.

10. Procédé selon la revendication 9 comprenant en outre l'étape consistant à former au moins une boucle (46d ; 52d ; 74f) connectant lesdits premier et deuxième motifs de chiffre 8, ladite au moins une boucle complète (46d ; 52d ; 74f) définissant un troisième plan qui est perpendiculaire auxdits premier et deuxième plans.

11. Procédé selon la revendication 10 dans lequel l'étape consistant à former au moins une boucle (46d ; 52d ; 74f) connectant lesdits premier et deuxième motifs de chiffre 8 comprend l'étape consistant à former deux boucles (46a, 46d ; 52a, 52d ; 74e, 74f) définissant des troisième et quatrième plans qui sont tous deux perpendiculaires auxdits premier et deuxième plans.

12. Procédé selon la revendication 11 dans lequel l'étape consistant à former deux boucles (46a, 46d ; 52a, 52d ; 74e, 74f) définissant des troisième et quatrième plans qui sont tous deux perpendiculaires auxdits premier et deuxième plans comprend deux boucles (46a, 46d ; 52a, 52d ; 74e, 74f) définissant des troisième et quatrième plans qui sont tous deux perpendiculaires auxdits premier et deuxième plans et sont en outre parallèles l'un par rapport à l'autre.

13. Procédé selon la revendication 9 dans lequel l'étape consistant à former des première et deuxième boucles (52b, 52c) dans un premier motif de chiffre 8 contenu relativement dans un premier plan comprend l'étape consistant à former au moins une boucle ouverte (52b, 52c), et/ou dans lequel l'étape consistant à former des troisième et quatrième boucles (52e, 52f) dans un deuxième motif de chiffre 8 contenu relativement dans un deuxième plan comprend l'étape consistant à former au moins une boucle ouverte (52e).

14. Procédé selon l'une quelconque des revendications 9 à 13, dans lequel ladite bobine complexe (40, 50, 70) est une bobine complexe (40, 50, 70) selon l'une quelconque des revendications 1 à 8, ledit procédé comprenant l'utilisation d'un composant (42, 60) pour former ladite bobine complexe (40, 50, 70).

FIG. 1

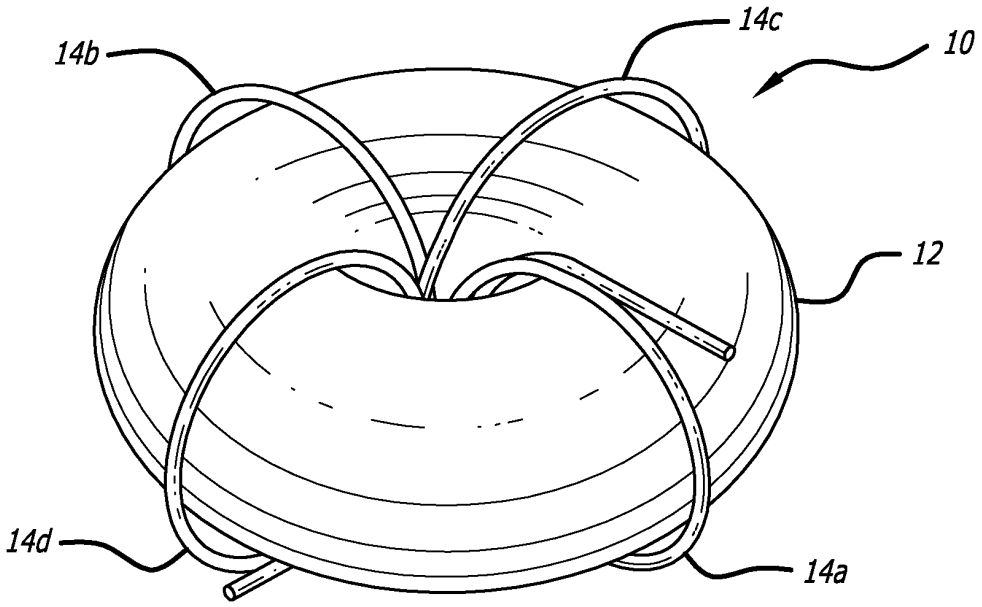


FIG. 2

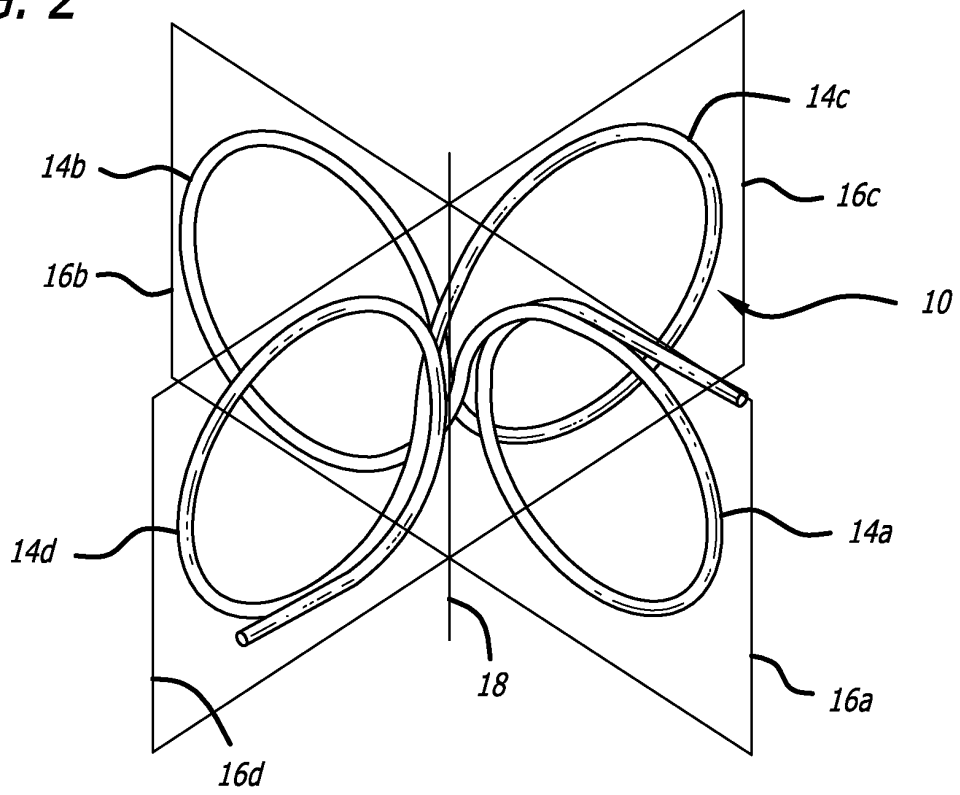


FIG. 3

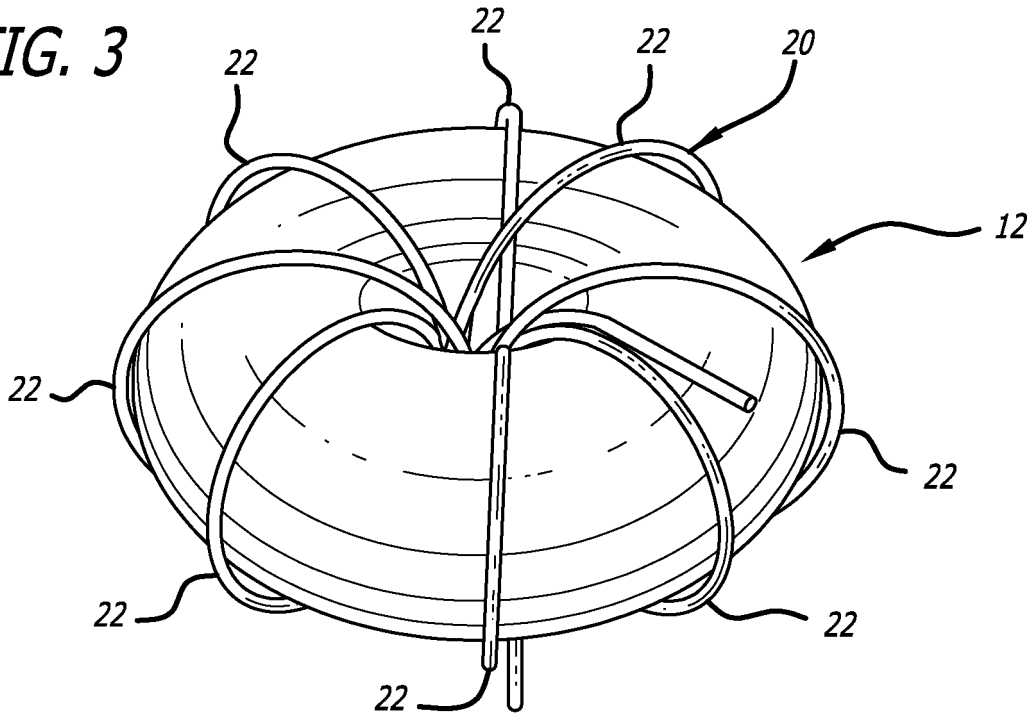


FIG. 4

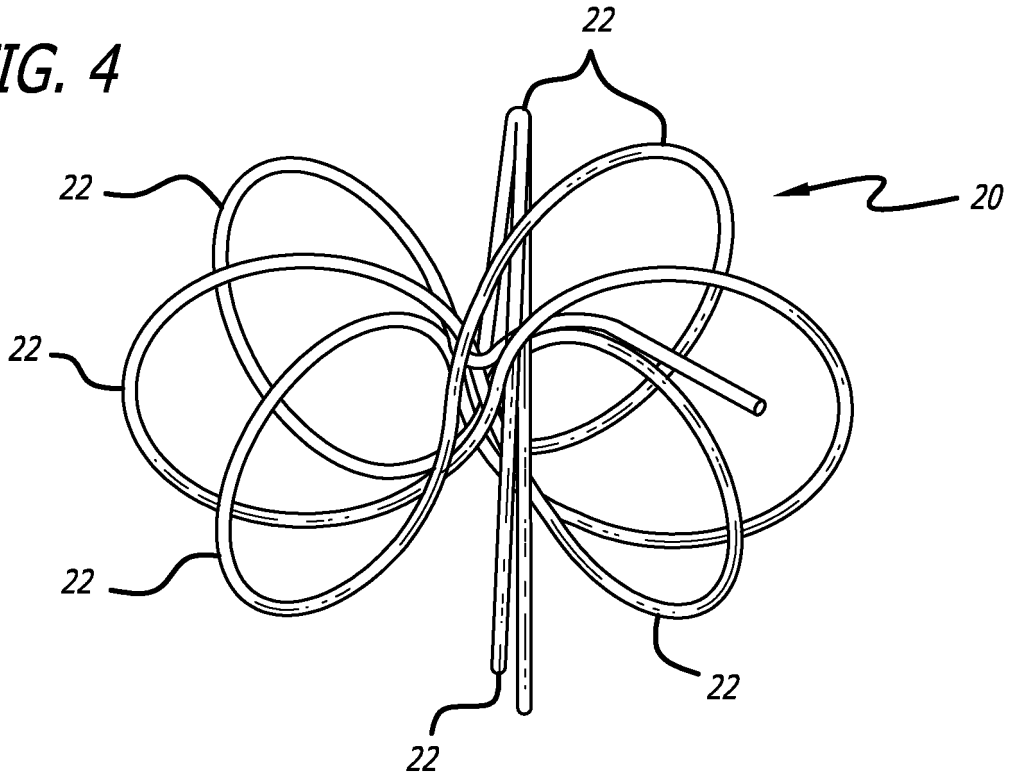


FIG. 5

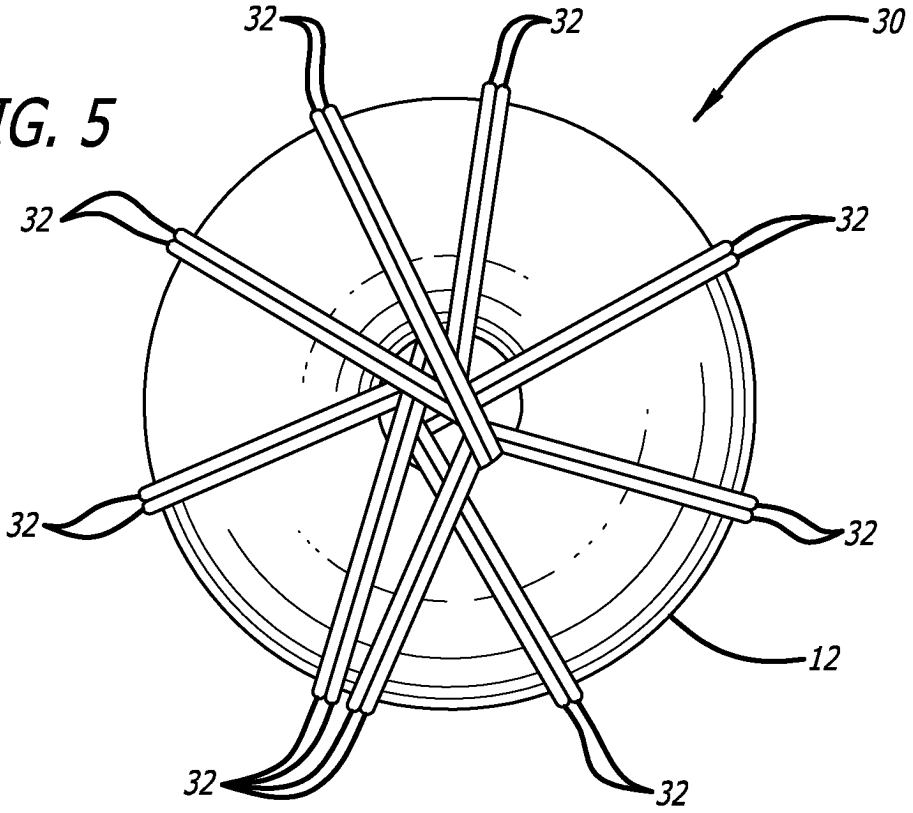


FIG. 6

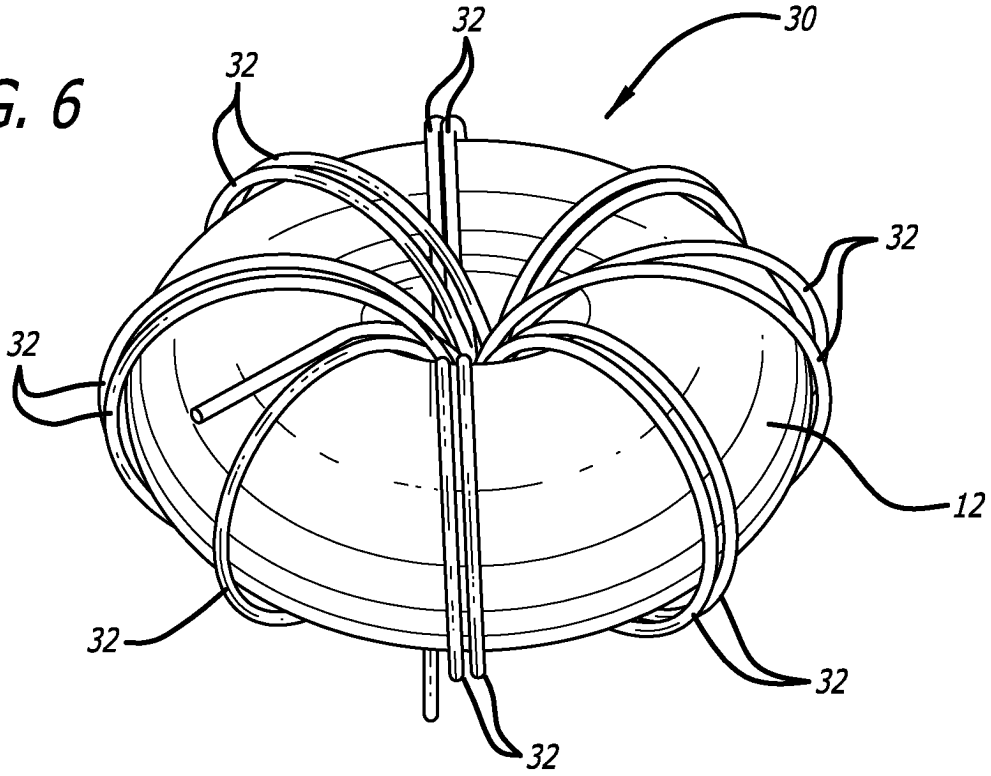


FIG. 7

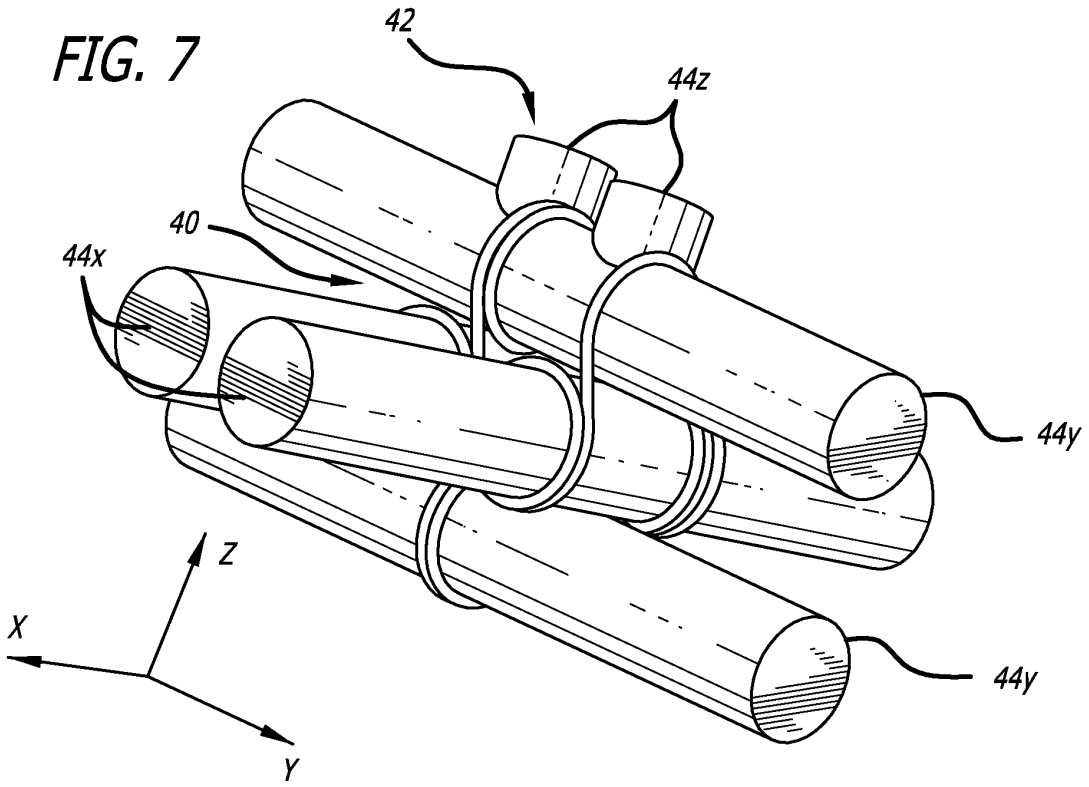


FIG. 8

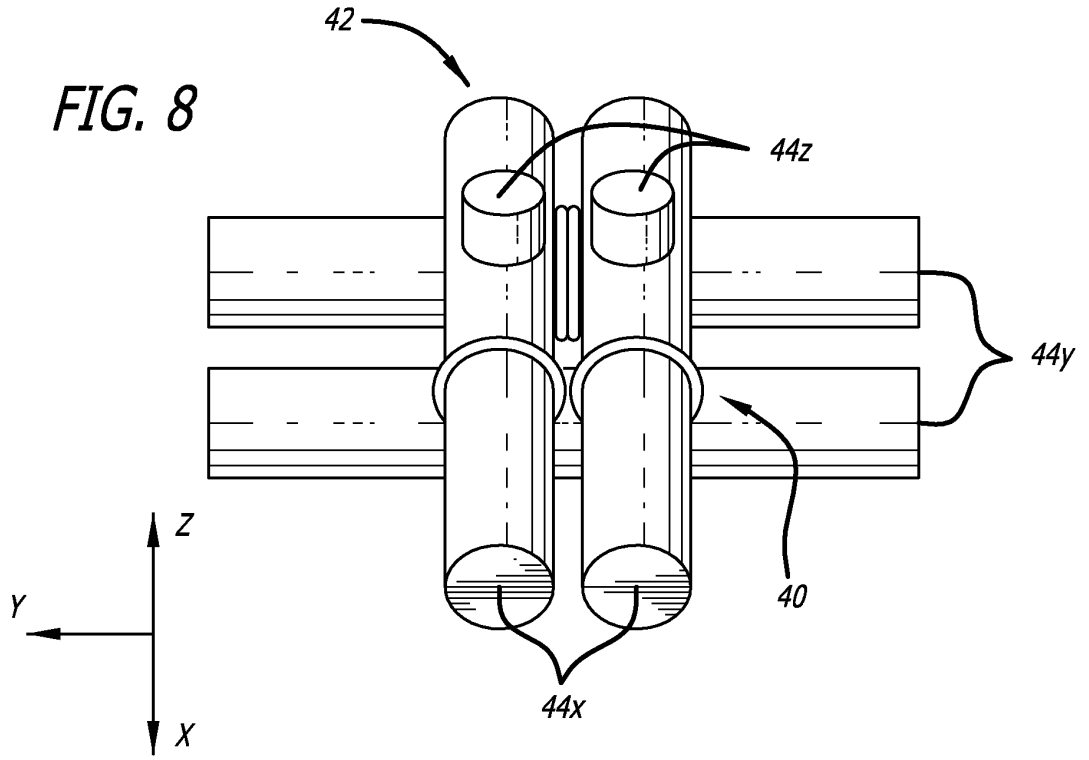


FIG. 9

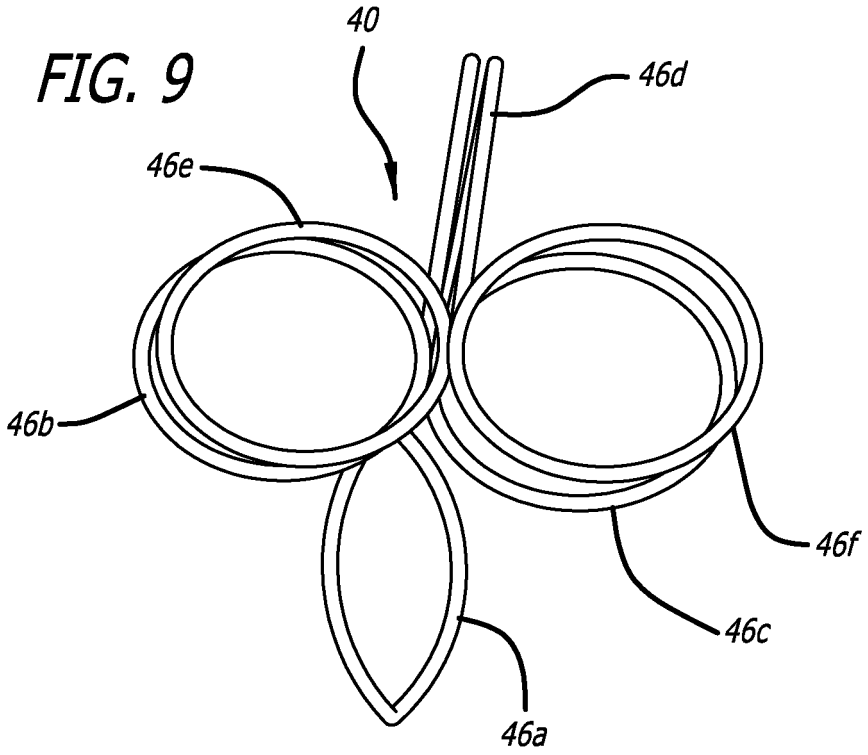


FIG. 10

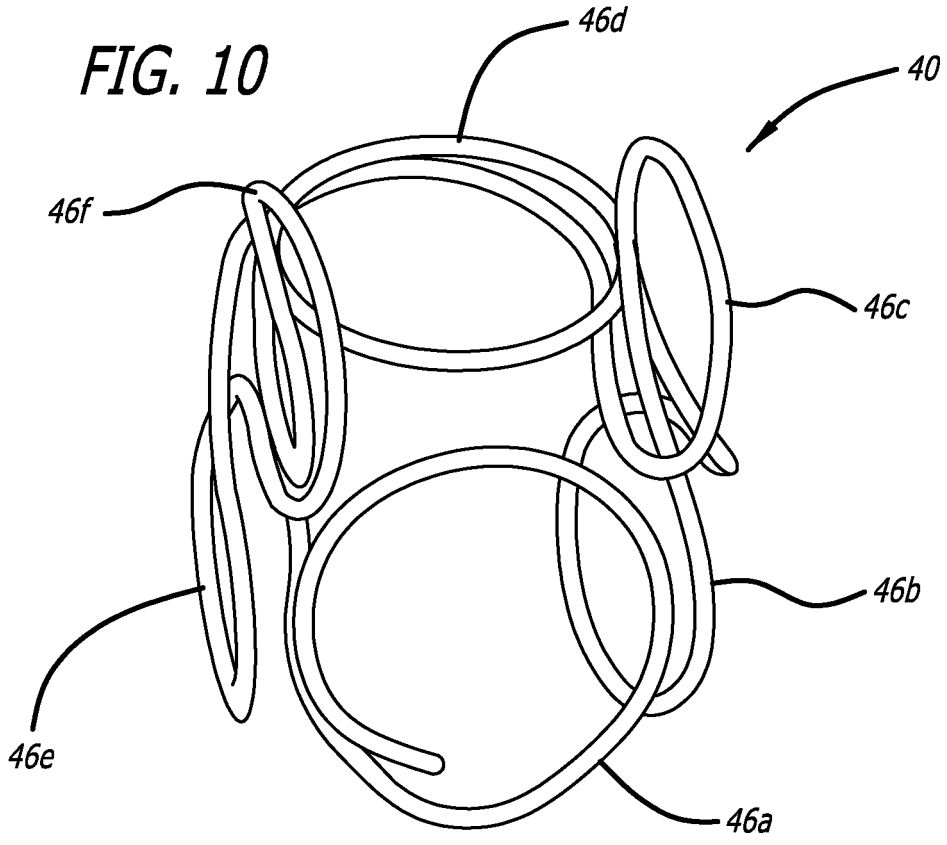
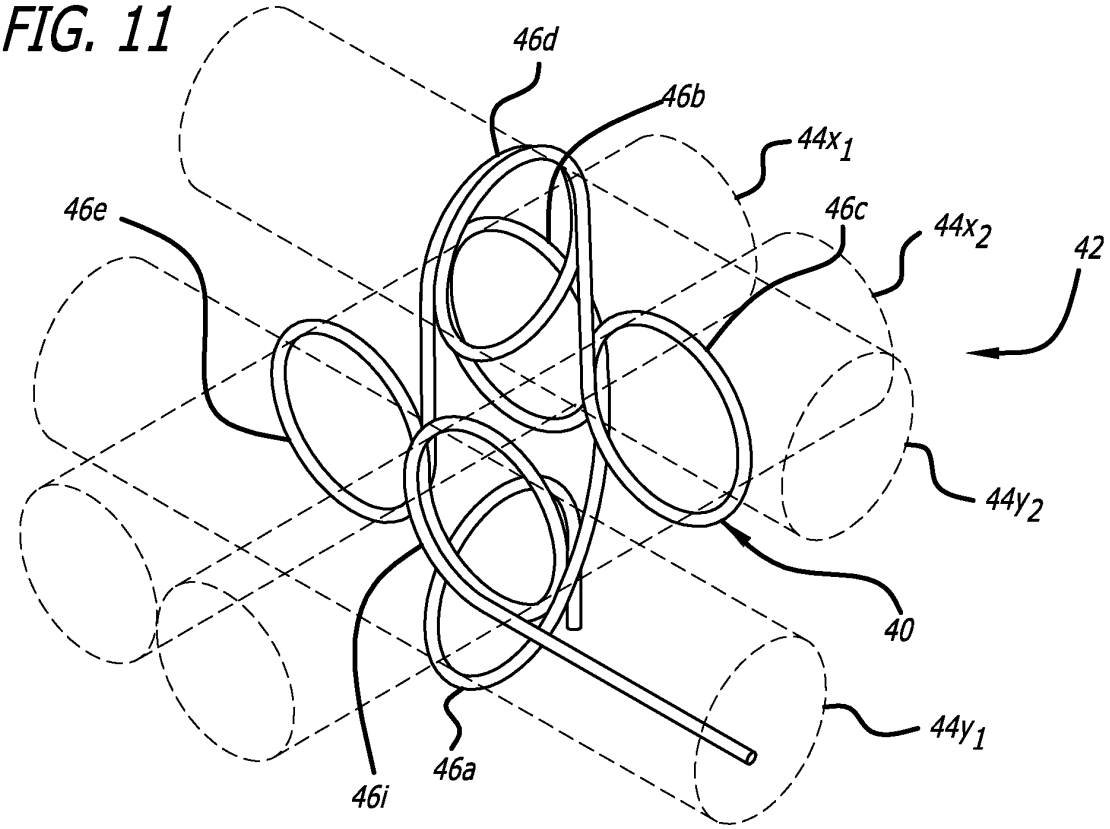


FIG. 11


46d
46b
44x1
46e
46c
44x2
42
44y2
40
44y1
46i
46a

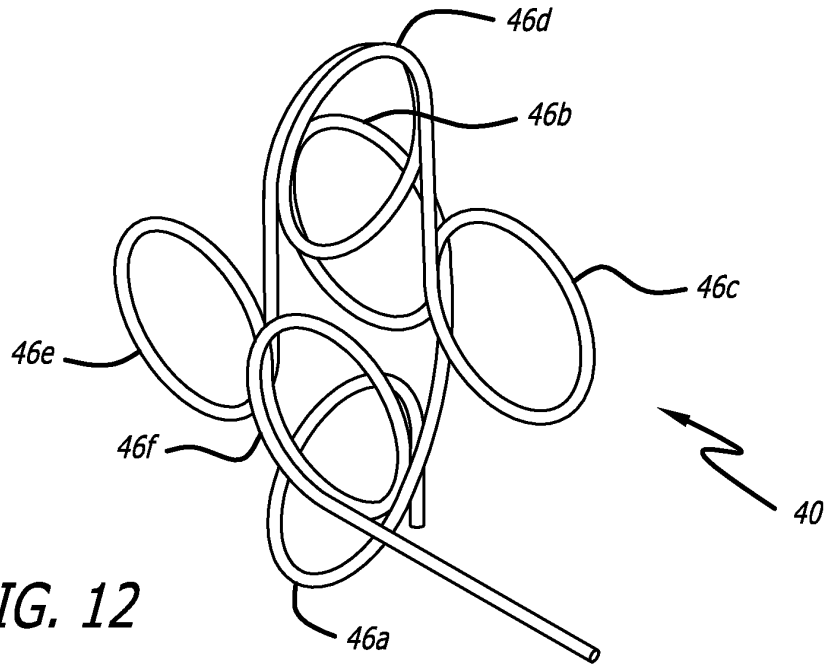

46d
46b
46c
46e
46f
40
46a

FIG. 12

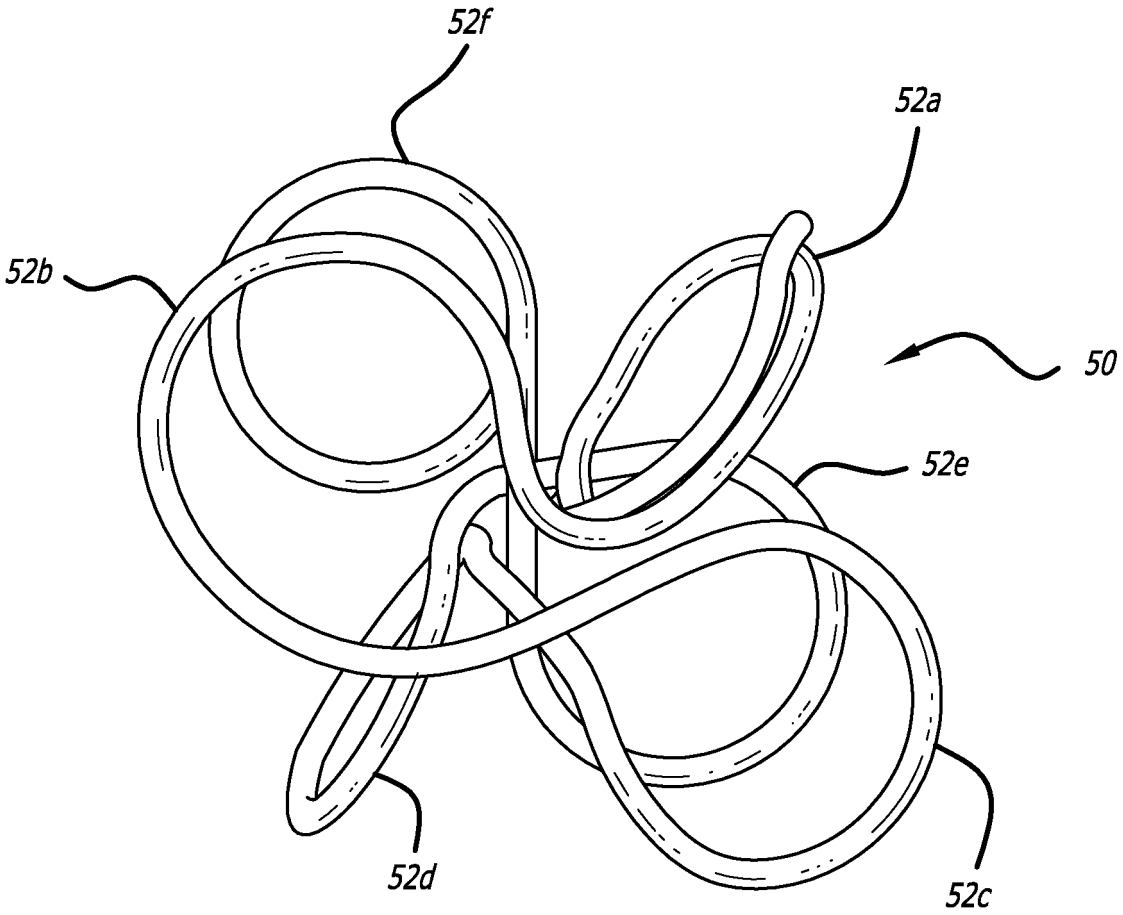
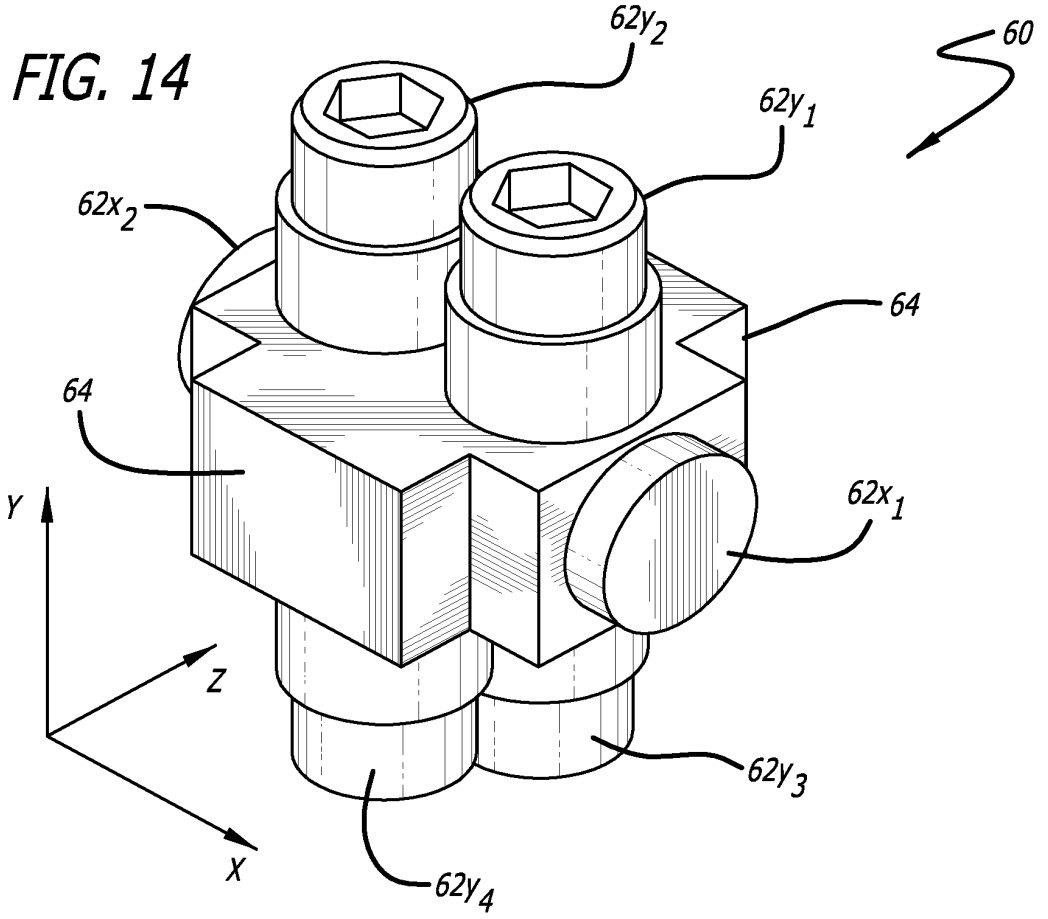


FIG. 13

FIG. 14


62y2
60
62y1
62x2
64
64
62x1
Y
Z
62y3
X
62y4

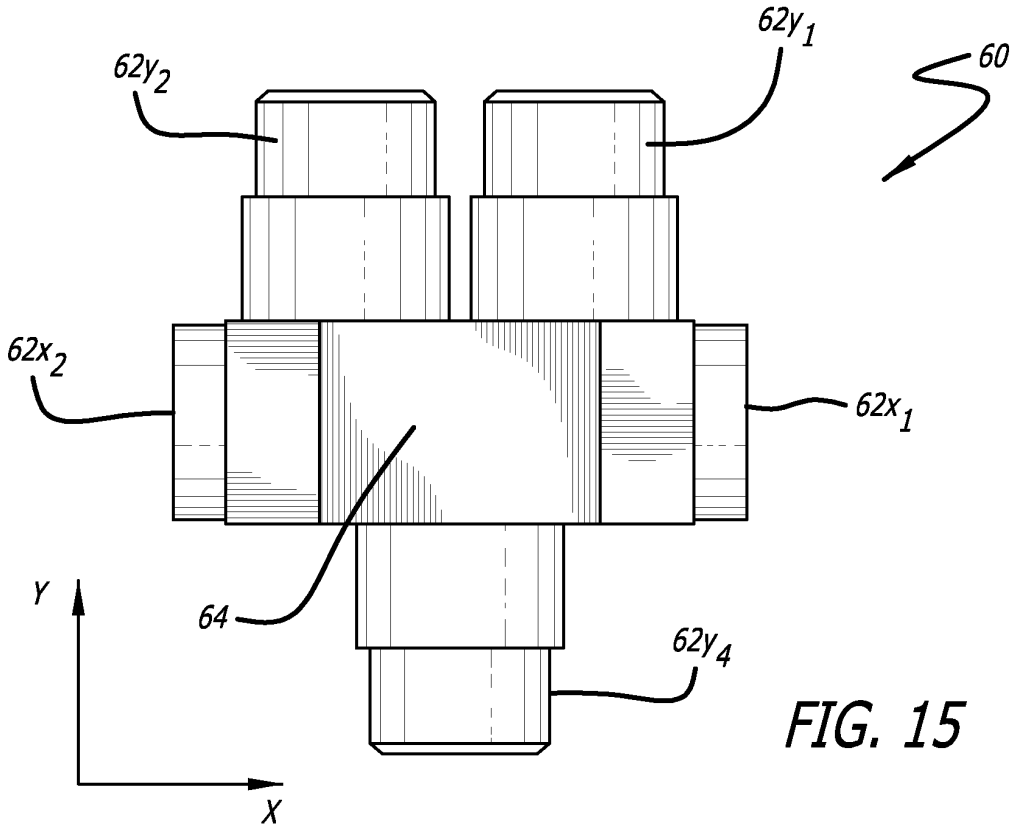

62y1
62y2
60
62x2
62x1
64
62y4
Y
X

FIG. 15

FIG. 16

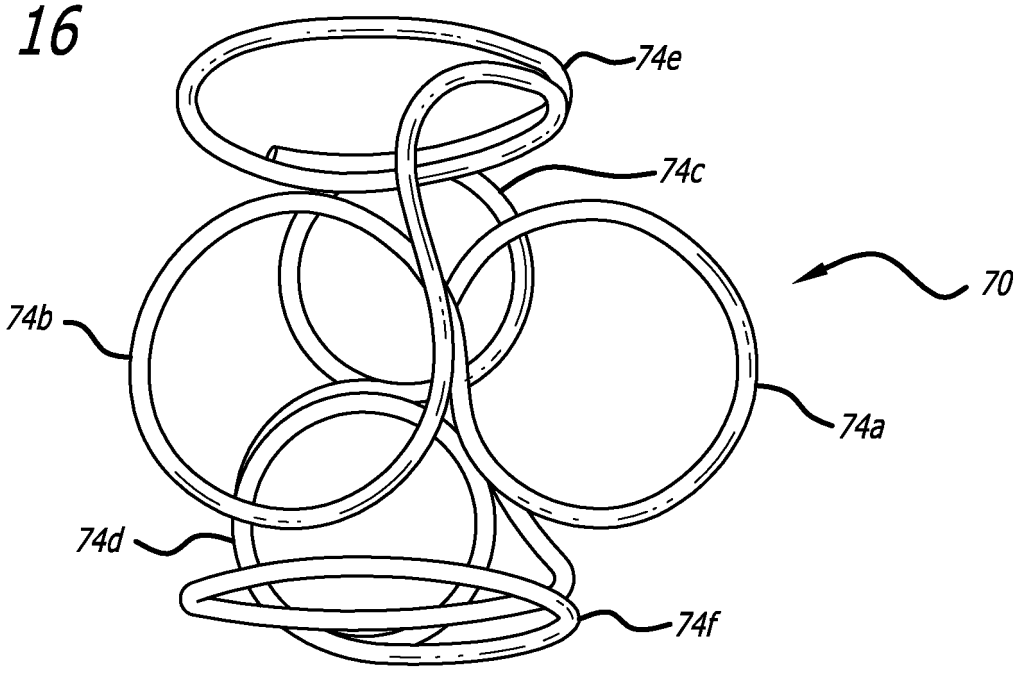


FIG. 17

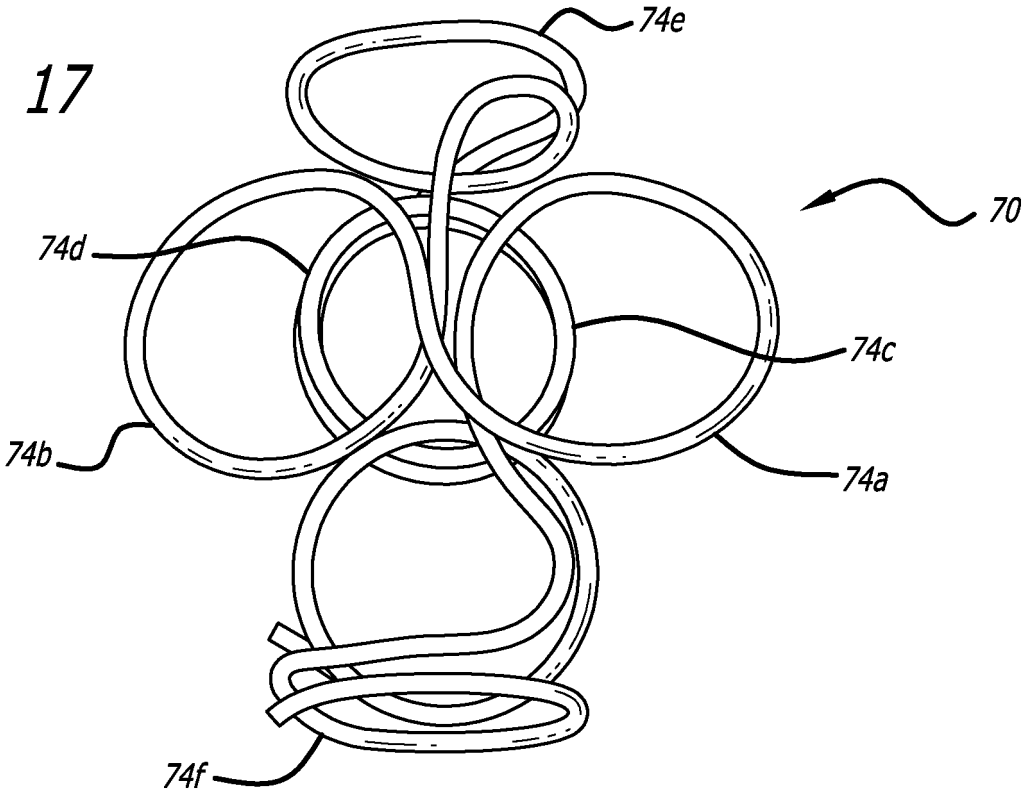


FIG. 18

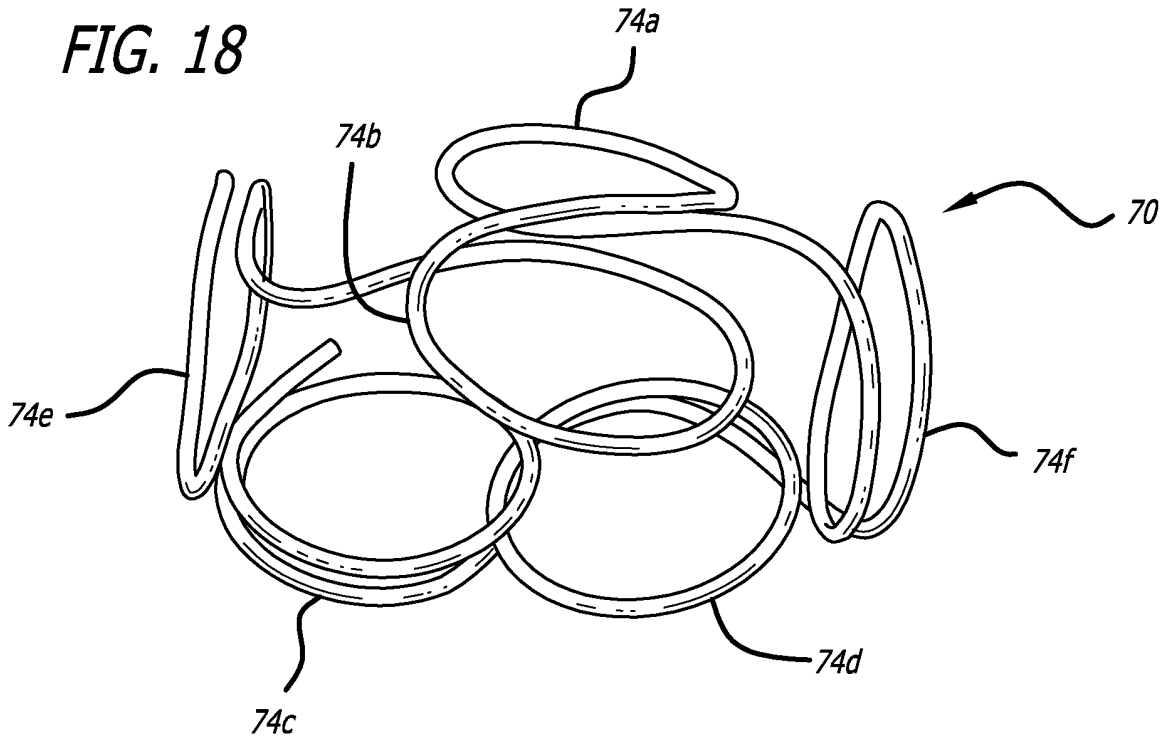
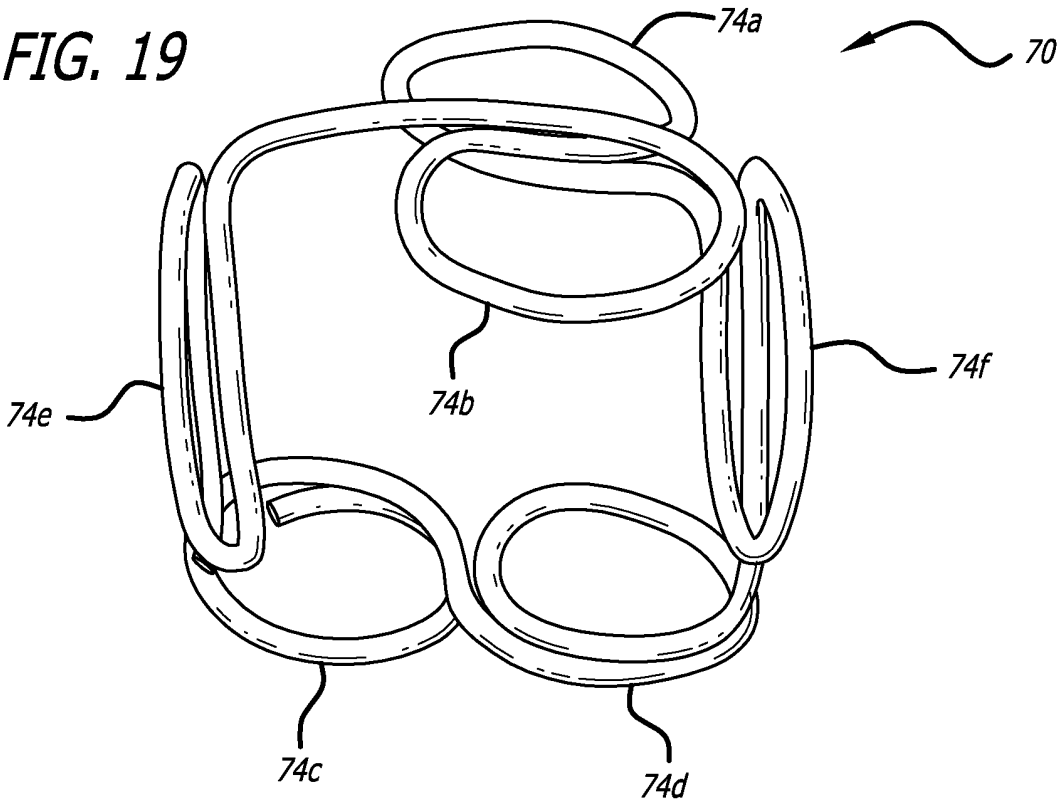


FIG. 19



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